1. Role of the CCT Program

Introduction

Over the past quarter century, both the national and international energy pictures have been one of dynamic change. These include the oil embargoes of the 1970s and the environmental debates of the 1980s. The 1990s brought about more changes in response to required emission reductions for acid rain precursors, initiation of more stringent NO_x standards for ozone nonattainment areas, tighter standards on fine particulates, the beginning of electric utility restructuring, and concern about global warming.

Since 1985, a joint effort between government and industry, known as the Clean Coal Technology Demonstration Program (CCT Program), has responded to the challenges resulting from these dynamic changes. The magnitude of the projects and extent of industry participation in the CCT Program is unprecedented. More than $5.4 billion is being expended, with industry and state governments investing two dollars for every federal government dollar invested. With 60 percent of the projects having completed operations by the end of fiscal year 1999, the technological successes have manifested themselves in the marketplace. New technologies to reduce the emissions of acid rain precursors, namely sulfur dioxide (SO_2) and nitrogen oxides (NO_x), are now in the marketplace and are being used by electric power producers and heavy industry. Advanced electric power generation systems that generate electricity with greater efficiency and fewer environmental consequences are now operating with the nation's most plentiful fossil energy resource—coal. Coal, which accounts for over 94 percent of the proven fossil energy reserves in the United States, supplies the bulk of the low-cost, reliable electricity vital to the nation's economy and global competitiveness. According to the U.S. Department of Energy's (DOE) Energy Information Administration (EIA) *Annual Energy Review 1998* (July 1999) (*AER98*), 933 million tons of coal were used to produce over 1,872 billion kilowatt-hours or 52 percent of the nation's electricity in 1998. EIA projections count on coal continuing to dominate electric power production, at least through 2020 (the end of the forecast period). In the *Annual Energy Outlook 2000* (December 1999) (*AEO2000*), EIA estimates 1,177 million tons of coal will generate an estimated 2,347 billion kilowatt-hours or nearly 49 percent of all electricity generated in 2020.

The ability of coal and coal technologies to respond to the nation's need for low-cost, reliable electricity hinges on the ability to meet two central requirements: (1) environmental performance requirements established in current and emerging laws and regulations, and (2) operational and economic performance requirements to compete in the era of utility restructuring and competition. The CCT Program is responding to these requirements by producing a portfolio of advanced coal-based technologies that will enable coal to retain its prominent role in the nation's power generation future. Furthermore, advanced technologies emerging from the CCT Program will also enhance coal's competitive position in the industrial sector. For example, technology advances in steel making, involving direct use of coal, will reduce the cost of production while greatly improving environmental performance. Also, coal could increase its market share in the industrial sector through cogeneration (steam and electricity) and coproduction of products (clean fuels and chemicals).

While the CCT Program responds to domestic needs for competitive and clean coal-based technology, it also positions U.S. industry to compete in a burgeoning power market abroad. Electricity continues to be the most rapidly growing form of energy consumption in the world. Projections from EIA's *International Energy Outlook 1999* (March 1999) (*IEO99*) show electricity rising from 12 trillion kilowatt-hours in 1996 to almost 22 trillion kilowatt-hours in 2020. The strongest growth is projected for the coal-dependent developing countries of Asia. This growth not only represents a tremendous market opportunity, but an opportunity to make a reduction in global carbon emissions through the application of highly efficient clean coal technologies.

Coal Technologies Respond to Need

The environmentally sound and competitive performance of modern coal technologies has evolved through many years of industry and government research, development, and demonstration (RD&D). The programs were pursued to assure that the U.S. recoverable coal reserves of 274 billion tons, which represent a secure, low-cost energy source, could continue to supply the nation's energy needs economically and in an environmentally acceptable manner.

During the 1970s and early 1980s, many of the government-sponsored technology demonstrations focused on synthetic fuels production technology. Under the Energy Security Act of 1980, the Synthetic Fuels Corporation (SFC) was established for the purpose of reducing the U.S. vulnerability to disruptions of crude oil imports.

The SFC's purpose was accomplished by encouraging the private sector to build and operate synthetic fuel production facilities that would use abundant domestic energy resources, primarily coal and oil shale. The strategy was for the SFC to be primarily a financier of pioneer commercial and near-commercial scale facilities. The goal of the SFC was to achieve production capacities of 500,000 barrels per day of synthetic fuels by 1987 and 2 million barrels per day by 1992, at an estimated cost of $8.8 billion.

By 1985, it became apparent that the need for synthetic fuels had changed, as oil prices declined, world oil supplies stabilized, and a short-term supply buffer was provided by the Strategic Petroleum Reserve. In 1986, Congress responded to the decline of private-sector interest in the production of synthetic fuels in light of these market conditions. Public Law 99-190, Department of the Interior and Related Agencies Appropriations Act for Fiscal Year 1986, abolished the SFC and transferred project management to the Treasury Department.

The CCT Program was initiated in October 1984. Public Law 98-473, Joint Resolution Making Continuing Appropriation for Fiscal Year 1985 and Other Purposes, provided $750 million from the Energy Security Reserve to be deposited in a separate account in the U.S. Treasury entitled The Clean Coal Technology Reserve. The nation moved from an energy policy based on synthetic fuels production to a more balanced policy. This policy established that the nation should have an adequate supply of energy, maintained at a reasonable cost, and consistent with environmental, health, and safety objectives. Energy stability, security, and strength were the foundations for this policy. Coal was recognized as an essential element in this energy policy for the foreseeable future because of the following:

- The location, magnitude, and characteristics of the coal resource base are well understood.
- The technology and skilled labor base to safely and economically extract, transport, and use coal are available.
- A multi-billion dollar infrastructure is in place to gather, transport, and deliver this valuable energy commodity to serve the domestic and international marketplace.
- Coal is used to produce over half of the nation's electric power and is vital to industrial processes, such as steel and cement production, as well as industrial power.
- This abundant fossil energy resource is secure within the nation's borders and relatively invulnerable to disruptions because of the coal industry's production responsiveness and stockpiling capability.
- Coal is the fuel of necessity in many lesser developed economies, which provides export opportunities for U.S.-developed, coal-based technologies.

Congress recognized that the continued viability of coal as a source of energy was dependent on the demonstration and commercial application of a new generation of advanced coal-based technologies characterized by enhanced operational, economic, and environmental performance. The CCT Program was established to demonstrate the commercial feasibility of clean coal technology applications in response to that need. In 1986, the first solicitation (CCT-I) for clean coal technology projects was issued. The CCT-I solicitation resulted in a broad range of projects being selected in four major product markets—environmental control devices, advanced electric power generation, coal processing for clean fuels, and industrial applications.

In 1987, the CCT Program became the centerpiece for satisfying the recommendations contained in the *Joint Report of the Special Envoys on Acid Rain* (1986). A presidential initiative launched a five-year, $5-billion U.S. government/industry effort to curb precursors of acid rain formation—SO_2 and NO_x. Thus, the second solicitation (CCT-II) issued in February 1988 provided for the demonstration of technologies that were capable of achieving significant emission reductions in SO_2, NO_x, or both, from existing power plants. These technologies were to be more cost-effective than current technologies and capable of commercial deployment in the 1990s. In May 1989, a third solicitation (CCT-III) was issued with essentially the same objective as the second, but additionally encouraged technologies that would produce clean fuels from run-of-mine coal.

The next two solicitations recognized emerging energy and environmental issues, such as global climate change and capping of SO_2 emissions, and thus focused on seeking highly efficient, economically competitive, and low-emission technologies.

Specifically, the fourth solicitation (CCT-IV), released in January 1991, had as its objective the demonstration of energy efficient, economically competitive technologies capable of retrofitting, repowering, or replacing existing facilities while achieving significant reductions in SO_2 and NO_x emissions. In July 1992, the fifth and final solicitation (CCT-V) was issued to provide for demonstration projects that significantly advanced the efficiency and environmental performance of technologies applicable to new or existing facilities. As a result of these five solicitations, a total of 60 government/industry cost-shared projects were selected, of which 40 valued at more than $5.4 billion have either been successfully completed or remain active in the CCT Program.

The success of the government/industry CCT Program is directly attributable to the CCT Program's responsiveness to public and private sector needs to reduce environmental emissions and maximize economic and efficient energy production. The CCT Program will strengthen the economy, enhance energy security, and reduce the vulnerability of the economy to global energy market shocks.

Coal Technologies for Environmental Performance

SO_2 Regulation

Acid Rain Mitigation. During the late 1980s, work began on drafting what was to become the Clean Air Act Amendments of 1990 (CAAA). On November 15, 1990, Congress enacted the CAAA as Public Law 101-549. Title IV, Acid Deposition Control, established emissions reduction targets for SO_2 and capped SO_2 emission in the post-2000 timeframe. Title IV is the first large-scale approach to regulating overall emissions levels by using marketable allowances. The utilities can adopt a control strategy that is most cost-effective for their given systems and plants rather than having to apply a "command-and-control" approach wherein the emission-reduction method is specified.

The emission reduction requirements for SO_2 were to be met in two phases. Phase I, which provided for the initial increment of SO_2 reduction, began on January 1, 1995. The second increment implemented through Phase II began January 1, 2000. Title IV identified 261 generating units (designated as "affected units") that were required to comply with Phase I. Most of these units are coal-fired with fairly high emission rates. Exhibit 1-1 summarizes the compliance methods used by the 261 affected units listed in Title IV to satisfy Phase I requirements. An additional 174 units participated in Phase I based on U.S. Environmental Protection Agency (EPA) rules that allow a utility to designate substitution or compensating units as part of Phase I compliance strategies. Therefore, 435 units are considered Phase I units. Under Phase II, more than 2,500 units are affected.

As a result of Phase I, SO_2 emissions at electric utilities declined from 15.6 million tons in 1990 to 12.5 million tons in 1997, a 20 percent decline. As shown in Exhibit 1-1, switching to low-sulfur coal was the option chosen by more than half of the owners of Phase I affected units.

In Phase II, beginning in 2000, emission constraints on Phase I plants are tightened, and limits are set for the remaining 2,500 boilers at 1,000 plants. With allowance banking, SO_2 emissions are expected to decline to 11.6 million tons in 2000 and 9.2 million tons by 2010, and will essentially remain at that level through 2020, the end of the forecast period of *AEO2000*. Since allowance prices are expected to increase after 2000, EIA predicts that 21

Exhibit 1-1
Phase I SO_2 Compliance Methods

Method	No. of Units	% of Units	% SO_2 Reduction from 1985 Baseline	% of Total SO_2 Reduction
Fuel switching/blending	136	52	60	59
Additional SO_2 allowances	83	32	16	9[a]
Scrubbers	27	10	83	28
Retirements	7	3	100	2
Other[b]	8	3	86	2
Total	261	100	345	100

[a]Includes reduced coal consumption of 2.5 million tons and 16% reduction in sulfur content.
[b]Includes 1 repowered unit, 2 switched to natural gas, and 5 switched to No. 6 fuel oil. Source: *The Effects of Title IV of the Clean Air Act Amendments of 1990 on Electric Utilities: An Update*, Energy Information Administration, March 1997.

GWe of capacity will be retrofitted with scrubbers to meet the Phase II goals.

Several projects within the CCT Program, listed below, were designated affected units and were required to achieve compliance with Phase I requirements:

- Northern Indiana Public Services Company's Bailly Generating Station, 528-MWe Unit Nos. 7 and 8 (Pure Air advanced flue gas desulfurization scrubber);
- Georgia Power Company's Plant Yates, 100-MWe Unit No. 1 (Chiyoda Thoroughbred-121 advanced flue gas desulfurization scrubber);
- New York State Electric & Gas Corporation's Milliken Station, 300-MWe Unit Nos. 1 and 2 (S-H-U formic-acid-enhanced wet limestone scrubber); and
- PSI Energy's Wabash River Station, 262-MWe Unit No. 1 (repowered with Destec integrated gasification combined-cycle unit).

The three Phase I scrubber projects served to redefine the state-of-the-art in wet limestone scrubber technology and the other was the first to introduce integrated gasification combined-cycle as a repowering technology. The advanced scrubbers essentially halved the cost of conventional scrubbers of the time. The repowering project represented an option provided under the CAAA that allows a four-year extension (to December 31, 2003) for compliance with Phase II requirements when advanced electric power generation technology is applied. Together with the other projects, the CCT Program has afforded a portfolio of SO_2 compliance options for the diverse fleet of existing coal-fired electric generating units and the means to meet future energy and environmental demands. These include advanced scrubbers, low-capital-cost sorbent injection systems, clean high-energy-density fuels from both eastern and western coals, and a range of advanced electric power generation systems.

NO_x Regulation

Acid Rain Mitigation. In Title IV of the CAAA, Congress also required the EPA to establish annual allowable emissions limitations for NO_x in two phases. Phase I required NO_x reductions from tangentially-fired and dry-bottom wall-fired boilers. These boilers are referred to as Group 1 boilers. In March 1994, EPA promulgated a rule establishing NO_x emission limitations of 0.45 lb/10^6 Btu for tangentially-fired units and 0.50 lb/10^6 Btu for wall-fired units. Ultimately, a compliance date of January 1, 1996, was established.

On December 19, 1996, EPA issued a rule to implement Phase II. The rule established NO_x emission limitations for additional coal-fired boilers (Group 2) and reduced the NO_x emissions limitations on Group 1 boilers. The types of Group 1 and 2 boilers and the Phase I and II NO_x emission limits are shown in Exhibit 1-2.

In response to the need to formulate NO_x emission reductions that were realistic and achievable for Group 1, EPA was able to use data developed during the Southern Company Services' evaluation of NO_x control technologies on wall-fired and tangentially-fired boilers. Furthermore, operational, environmental, and economic data on NO_x controls were developed under the CCT Program for all four major boiler types (wall-fired, tangentially-fired, cyclone-fired, and cell-burner), which constitute over 90 percent of the pre-New Source Performance Standard (NSPS) boiler types. In addition, low-NO_x burners were installed and tested on

Exhibit 1-2
CAAA NO_x Emission Limits

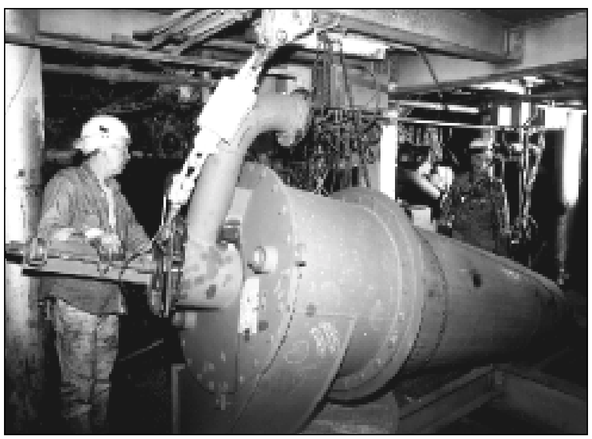
Group 1 Boiler Type	Group 2 Boiler Type	Phase I NO_x Emission Limits[a] (lb/10^6Btu)	Phase II NO_x Emission Limits[a] (lb/10^6 Btu)
Tangentially-fired boilers		0.45	0.40
Dry-bottom wall-fired boilers[b]		0.50	0.46
	Cell-burner boilers		0.68
	Cyclone boiler >155 MWe		0.86
	Wet-bottom wall-fired boilers >65 MWe		0.84
	Vertically fired boilers		0.80

[a]Emission limits are lb/10^6Btu of heat input on an annual average basis.

[b]Other than units applying cell-burner technology.

a vertically-fired boiler. Low-NO_x burners were developed for all boiler types amenable to burner modification. As a result, nearly half of the pre-NSPS boilers are equipped with low-NO_x burners (LNB). The CCT Program also demonstrated a range of NO_x control techniques to address boilers where burner modification is not practical and to provide methods to enhance NO_x control beyond low-NO_x burner capability. These options included coal and gas reburning, selective noncatalytic reduction (SNCR), and selective catalytic reduction (SCR). This portfolio of NO_x controls not only will assure that Phase I and II emission reductions are achievable, but will provide the technology base necessary to achieve even greater NO_x reductions that may be necessary to meet CAAA Title I requirements or new National Ambient Air Quality Standards (NAAQS) for ozone.

Soot and Smog. The Clean Air Act requires EPA to promulgate and periodically revise NAAQS for each air pollutant identified by the agency as meeting certain statutory criteria. For each pollutant, EPA sets a "primary standard" (a concentration level "requisite to protect the public health" with an "adequate margin of safety") and a "secondary standard" (a level "requisite to protect the public welfare"). In July 1997, EPA issued final rules revising the primary and secondary NAAQS for particulate matter ("PM") and ozone (O_3) (commonly referred to as "soot and smog" regulations).

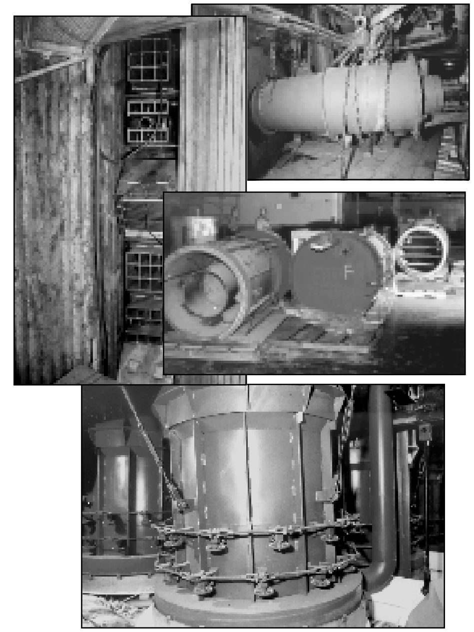


▲ NO_x emissions at Georgia Power's Plant Hammond were reduced by 63 percent with Foster Wheeler's low-NO_x burners, shown here, and advanced overfire air.

For ozone, the standard was tightened from 0.12 parts per million (or 120 parts per billion) of ozone measured over one hour to a new standard of 0.08 parts per million (or 80 parts per billion) measured over eight hours, with the average fourth highest concentration over a three-year period determining whether an area is out of compliance. (Particulate matter rules are addressed later.)

On May 14, 1999, the U.S. Court of Appeals for the District of Columbia Circuit remanded EPA's "soot and smog" regulations, challenging EPA's legal rationale as well as EPA's authority to enforce any new ozone standard under the CAAA. The court did not challenge the underlying science. The Department of Justice filed a petition for rehearing by the full court on June 28, 1999. As of the end of FY99, EPA is awaiting the court's decision on whether to rehear the case.

EPA is considering reinstating the old one-hour ozone standard nationwide. Since issuing the more protective 8-hour ozone standard, EPA has revoked the one-hour standard in much of the country (wherever ozone levels met the old standard). But the court opinion now leaves much of the nation without an adequately enforceable standard for ground-level ozone pollution to guard against deterioration in air quality. EPA is concerned about that possibility in light of recent air quality data showing that the national average ozone level increased five percent in 1998.



▲ Low-NO_x burner technologies: ABB Combustion Engineering's LNCFS™ for tangentially-fired boilers (top left), Foster Wheeler's low-NO_x burner for wall-fired boilers (top right), Babcock & Wilcox's LNCB® for cell-burner boilers (center), and Babcock & Wilcox's DRB-XCL® for down-fired boilers (bottom).

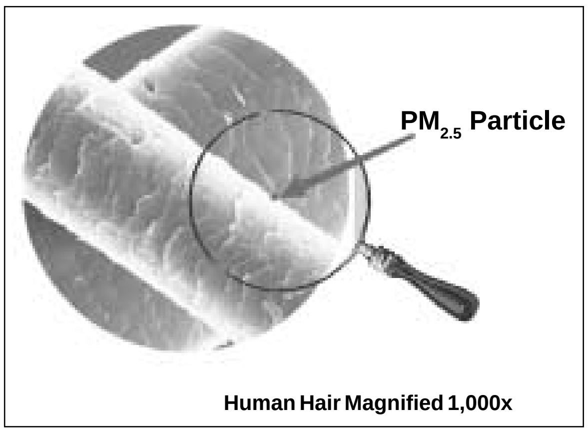
In addition to the nationwide soot and smog regulations, efforts are underway to address regional ozone issues.

Attainment of Ozone Standards (Title I). CAAA Title I established an ozone transport commission to address regional transport of pollutants that contribute to ozone nonattainment in the northeast United States. The Northeast Ozone Transport Commission approved a Memorandum of Understanding in September 1994 stipulating an intent to reduce power plant NO_x emissions (a precursor to ozone formation) by as much as 70 percent by 2003.

The Ozone Transport Assessment Group (OTAG), a collaborative effort of 37 states and the District of Columbia, was established in June 1995 to address the issue of ozone transport. In response to recommendations issued in June 1997 by the OTAG Policy Group, EPA issued a "SIP Call" to 22 states and the District of Columbia. The SIP Call (effective December 28, 1998, as EPA's Ozone Transport Rule) initially required these 23 jurisdictions to submit emission reduction plans by December 30, 1999, on how to cut NO_x emissions 85 percent below 1990 rates or achieve a 0.15 lb/10^6 Btu emission rate by May 2003. However, shortly after issuing its National Ambient Air Quality Standards (NAAQS) opinion, the Court of Appeals for the D.C. Circuit stayed the deadline for states to submit plans for complying with the SIP call pending further order of the court.

The EPA is also formulating a plan for utilities and industries to trade allowances for NO_x emissions. The "cap and trade" program would apply to the 23 jurisdictions affected by the SIP Call. Under the plan, the affected jurisdictions would establish a cap on NO_x emissions and then give power plants and industries the flexibility to cut NO_x emissions in the most cost-effective manner. Power plants and industries that cut NO_x emissions below the caps could sell credits to facilities that could not cut emissions as quickly or cost-effectively. The NO_x trading program, similar to the existing SO_2 trading program, allows sources to pursue various compliance strategies, such as fuel switching; installing pollution control devices, like the devices demonstrated in the CCT Program; or buying allowances from sources that over-complied.

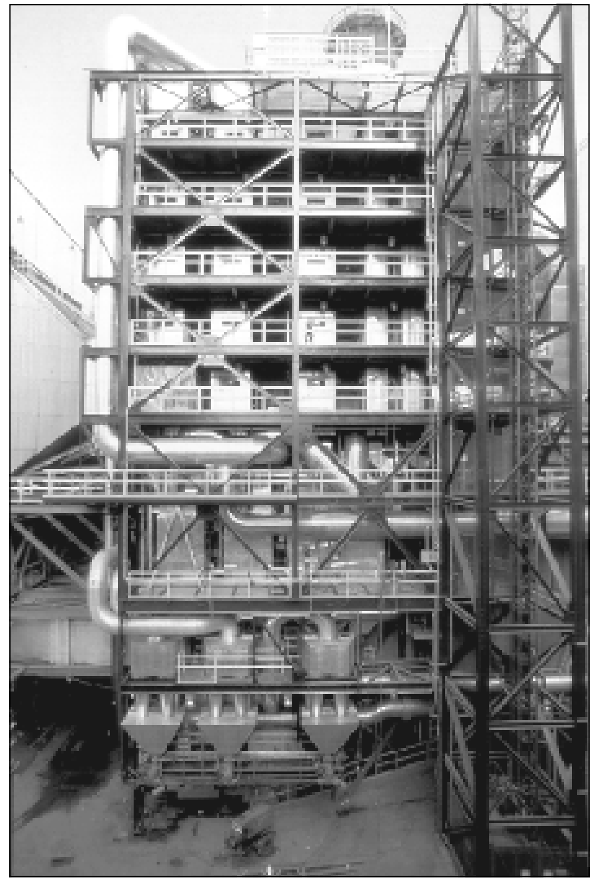
New Source Performance Standards. On the national level, the EPA has tightened its NO_x emission standards for new electric utility boilers and has changed its rules so that all generation fuels are treated the same. Under the revised New Source Performance Standard (NSPS), electric utility and industrial steam generating units built or modified after July 9, 1997, must meet an emission limit of 1.6 lb/MWh regardless of fuel type. For existing sources that become subject to NSPS, the NO_x limit will be 0.15 lb/10^6 Btu. By basing the standard on electricity output, there is an economic incentive to use more efficient systems.



▲ This picture illustrates how minute are $PM_{2.5}$ particles when compared to a human hair.

Particulate Regulation

Respirable particles. The standard for inhalable particles (PM_{10})—those measuring 10 microns in diameter and smaller—established under Title I of the CAAA remains essentially unchanged, while a new standard for respirable particles ($PM_{2.5}$)—those measuring 2.5 micrometers in diameter and smaller—was established under the new "soot and smog" regulations. The $PM_{2.5}$ regulations sets an annual limit of 15 micrograms per cubic meter, with a 24-hour limit of 65 micrograms per cubic meter under the "soot and smog" regulations mentioned above. The revisions to NAAQS for $PM_{2.5}$ could require additional SO_2 control because many sulfur species are in this size range. Establishing a reliable relationship between fine sulfate emissions and ambient $PM_{2.5}$ concentrations could have serious repercussions for coal burning facilities.



▲ Eight SCR catalysts with various shapes and compositions were evaluated side-by-side at Gulf Power's Plant Crist using high-sulfur coal. NO_x reductions of 80 percent were achieved.

Hazardous Air Pollutants

Hazardous Air Pollutant Monitoring. Under Title III of the CAAA, EPA is responsible for determining the hazards to public health posed by 189 hazardous air pollutants (HAPs), and is required to perform a study of HAPs to determine the public health risks that are likely to occur as a result of power plant emissions. To address this issue, DOE implemented a program with industry to monitor HAPs emissions at CCT Program project sites. Objectives of the HAPs monitoring are to (1) improve the quality of HAPs data being gathered, and (2) monitor a broader range of plant configurations and emissions control equipment. As a result of this program, 21 CCT projects are monitoring HAPs, with 11 having been completed by September 1999 (see Appendix C, Exhibit C-7).

In a parallel effort begun in January 1993, EPA, with the participation of DOE under the Coal Research and Development Program, the Electric Power Research Institute (EPRI), and the Utility Air Regulatory Group (UARG), began an emissions data collection program using state-of-the-art sampling and analysis techniques. Emissions data were collected from eight utilities representing nine process configurations, several of which were sites for CCT projects. These utilities represented different coal types, process configurations, furnace types, and pollution control methods. The report, *A Comprehensive Assessment of Toxic Emissions from Coal-Fired Power Plants: Phase I Results from the U.S. Department of Energy Study*, was released in September 1996 and provided the raw data from the emissions testing. The second phase of the DOE/EPRI effort involves sampling at other sites, including the CCT Program's Wabash River, Tampa Electric, and Sierra Pacific integrated gasification combined-cycle (IGCC) projects.

In another DOE study, HAPs data were collected from 16 power plants and reported in *Summary of Air Toxics Emissions Testing at Sixteen Utility Plants*. The report, issued in July 1996, provides an assessment of HAPs measured in the coal, across the major pollution control devices, and emitted from the stack. The results of the HAPs program have significantly mitigated concerns about a broad range of HAPs emission from coal-fired power generation, and focused attention on mercury.

Mercury. Following up on the October 1996 EPA report to Congress, *Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generating Units—Interim Final Report* (final report was issued February 1998), a new report has been released by EPA focusing on mercury emissions. The *Mercury Study Report to Congress*, issued December 1997, estimates that the U.S. industrial sources were responsible for releasing 158 tons of mercury into the atmosphere in 1994 and 1995. The EPA estimates that 87 percent of those emissions originate from combustion sources such as waste and fossil fuel facilities, 10 percent from manufacturing facilities, 2 percent from area sources, and 1 percent from other sources. The EPA also identified four specific categories that account for about 80 percent of the total anthropogenic sources: coal-fired power plants, 33 percent; municipal waste incinerators, 18 percent; commercial and industrial boilers, 18 percent; and medical waste incinerators, 10 percent.

Global Climate Change

The CCT Program had its roots in the reduction of acid rain precursors and was responsive to the recommendations contained in the *Joint Report of the Special Envoys on Acid Rain,* as discussed earlier. Moreover, as concerns over global climate change emerged, the CCT Program began to emphasize demonstration of advanced electric power generation technology capable of achieving significantly higher efficiency than conventional systems, thus reducing carbon emissions.

For example, pressurized fluidized-bed combustion (PFBC) technology has efficiencies up to 25 percent higher than conventional coal-fired systems, which results in a like reduction in carbon emissions. Also, the PFBC technology reduces pollutant emissions far below NSPS, without expensive add-on emission controls. As a result of the CCT Program's Tidd PFBC Demonstration Project and associated

▲ Hazardous air pollutants were measured at the Babcock & Wilcox Company's Demonstration of Coal Reburning for Cyclone Boiler NO_x Control at Nelson Dewey Station.

development work, this technology is achieving market penetration, including several commercial sales of this new generation of advanced power system in Japan and Germany. The work at Tidd is also providing the basis for the second generation PFBC demonstrations to be conducted in Lakeland, Florida with funding from the CCT Program.

Another very efficient advanced power system is IGCC. There are four IGCC demonstration projects in the CCT Program, representing a diversity of gasifier types and cleanup systems. These projects are pioneering this environmentally friendly technology, which in addition to lower carbon emissions, boasts very low SO_2 and NO_x emissions. The IGCC technology offers flexibility in that new plants can be constructed in modules as demand dictates. Current worldwide market penetration of this technology is approximately 5 GW, and demand is growing.

Regional Haze

In July 1999, EPA published a new rule calling for long-term protection of and improvement in visibility for 156 national parks and wilderness areas across the country. Many environmental groups believe coal-fired power plants are a source of regional haze in the national parks and wilderness areas.

During the period 2003-2008, states are required to establish goals for improving visibility in each of these 156 areas and adopt emission reduction strategies for the period extending to 2018. States have flexibility to set these goals based upon certain factors, but as part of the process, they must consider the rate of progress needed to reach natural visibility conditions in 60 years. Coal-fired power plants are likely targets for new controls to reduce regional haze.

Solid Waste

The CCT Program also addresses the issue of solid waste. For example, several projects redefined the state-of-the-art in wet flue gas desulfurization. Included in this significant technology improvement was production of commercial-grade gypsum in lieu of the scrubber sludge associated with conventional scrubbers of the early 1990s. Scrubber sludge had been projected to require over 4,500 acres per year for disposal by 2015. Advances under the CCT Program precluded that need. The balance of technologies in the CCT Program also address solid waste concerns by producing salable by-products instead of wastes (e.g., sulfur, sulfuric acid, or fertilizer) or dry, environmentally benign materials. These dry materials can either be used as construction materials (e.g., for use in soil and road bed stabilization, or as a cement ingredient), agricultural supplements, a means to mitigate mine subsidence and acid mine drainage, or can be readily disposed of in landfills.

Toxics Release Inventory

Section 313 of the Emergency Planning and Community Right-To-Know Act (EPCRA) and section 6607 of the Pollution Prevention Act (PPA) mandates establishment of a publicly accessible database containing information on the release of toxic chemicals by facilities that manufacture, process, or otherwise use them. This database is known as the Toxics Release Inventory (TRI). Starting in 2000, electric utilities are required to report on releases of toxic chemicals into the air, water, and land. EPA compiles this data in an online TRI that gives the public access to detailed information about releases of toxic chemicals in their communities. It is expected that electric utilities will exceed chemical manufacturers as the largest emitters of toxic chemicals into the environment. Although the emission rates are low for electric utilities, the volume of emissions will likely bring pressure for further reductions.

Coal Technologies for Competitive Performance

When the CCT Program started in 1985, the electric utility industry was highly regulated. The major uncertainty was the breadth and depth of environmental regulatory requirements that would be imposed on the industry. Even this uncertainty was mitigated by the fact that the environmental control costs could be passed through to the consumer if approved by the state regulatory commission. As long as the utility made prudent investments in plant and equipment, their economic future was fairly stable and predictable. Most industry observers assumed that coal and nuclear energy would carry the burden of baseload generation, oil would be phased out, and natural gas would be used for meeting peak load requirements.

By mid-1997, the picture was entirely different—the utility industry was in the midst of a major restructuring to accommodate a competitive marketplace. Under utility restructuring, power generators must assume the risk for new capacity additions. The relatively low capital cost and short lead times for natural gas-based systems makes them the preferred option for the foreseeable future. As a result, projections now call for natural gas to be the fuel of choice for new capacity additions through 2020. During the same period, nuclear-based capacity will decline and coal-based capacity will increase moderately.

Consumers became a major factor in pushing for competition and regulatory reform even though regulators provide the oversight necessary to assure that consumers were paying a fair price. Consumer pressures for access to lower priced power have been successful in bringing about competition in retail as well as wholesale power markets. Deregulation of retail markets is occurring at the state level. (The Federal Energy Regulatory Commission (FERC) is prohibited from ordering retail wheeling.) Under the Energy Policy Act of 1992 (EPAct), states continue to have responsibility for regulating (1) any electric company operating within its jurisdiction, (2) any EWG selling electricity wholesale to such a utility, and (3) any holding company that was an associate or affiliate of an EWG selling power to a regulated utility. By the end of fiscal year 1999, twenty-one states had enacted legislation to allow competition in the retail electricity market in one form or another. In three other states, there have been comprehensive regulatory orders issued. Twenty-six states and the District of Columbia are currently investigating deregulation options. Only in two states is there no significant deregulation activity. Under retail deregulation, end users are not required to purchase power from their local utility company, but instead may purchase power from generators or marketers located in other states and regions of the country. In this competitive market environment, power is priced according to market conditions, not necessarily according to generation costs.

Advancement in the technology of electricity production is another factor that has had an impact on restructuring. Nonutility generators have taken advantage of these advances, such as aero-derived gas turbines, to generate electricity cheaper than can be achieved using conventional fossil steam or nuclear generators. The new technologies are often more efficient, less environmentally obtrusive, and can be installed in a very short period of time in capacity modules closely matching the load growth curves.

These factors have had a pronounced effect on the utility market for coal and clean coal technology. A comparison of 1985 and 1999 energy projections for coal, natural gas, and oil, which is shown in Exhibit 1-3, illustrates the magnitude of the change that restructuring is playing, as well as environmental regulation discussed previously. According to EIA's *AEO2000*, coal is projected to maintain its lead in the production of electricity in 2010 at 50 percent; however, that is down from 60 percent when the CCT Program started. The differential has been, for the most part, made up by the growth in natural gas power generation. Nuclear power's contribution to the nation's electric power generation in 2010 is expected to drop by almost 30 percent between the 1985 and 1999 projections.

Exhibit 1-3
Comparison of Energy Projections for Electric Generators

	Electricity Sales (10^9 kWh/yr)			Coal Consumption (10^6 tons/yr)			Gas Consumption[a] (10^{12} ft^3/yr)			Oil Consumption[a] (10^6 barrels/yr)		
	A	B	% dif	A	B	% dif	A	B	% dif	A	B	% dif
1995	3,018	3,026[b]	0.3	924	958[b]	3.7	3.0	3.37[b]	12	73	110	51
2010	4,176	3,909	-6.4	1,355	1,092	-19.4	1.7	6.45	279	146	77	-47

A *National Energy Policy Plan Projections to 2010,* U.S. Department of Energy, December 1985.

B *Annual Energy Outlook 2000 with Projections to 2020*, Energy Information Agency, December 1999.

% dif = percent difference between the two projections.

[a] Consumptions by electric generators excluding cogenerators.

[b] Actuals from *Annual Energy Outlook 1998*, December 1997.

Industry restructuring and competition will impact coal and coal technologies for the foreseeable future. Utilities are expected to improve their operating efficiencies by using existing plants at higher capacity factors. Contributing to increased capacity factors is a projected drop in generating capacity not only from nuclear plant retirements but capacity losses where stranded costs are not recovered. The EIA has projected that the capacity factor for coal-fired power plants will increase from 68 percent in 1998 to 83 percent in 2020. EIA further predicts that more than 21 GW of new coal-fired capacity is expected to come on line between 1998 and 2020, accounting for almost 7 percent of capacity expansion. During this time, new highly efficient low-emissions power systems will enter the power production markets. New concepts to reduce delivered electricity prices will likely be employed. Examples include minemouth plants that reduce or eliminate the coal transportation cost component in power production. Also, cogeneration and coproduction systems will be available, which allow the consumer's cost of electricity to be offset by the profitability of coproducts.

Coal Technologies to Sustain Economic Growth

It is in the national interest to maintain a multi-fuel energy mix to sustain national economic growth. Coal is a key component of national energy security because of its affordability, availability, and abundance within the nation's borders. The CCT Program's strategy leads to the development and deployment of a technology portfolio that enhances the efficient use of this coal resource while assuring that national and global environmental goals are achieved. The domestic coal resources are large enough to supply U.S. needs for more than 250 years at current rates of production.

The United States is increasingly dependent on imported oil as low prices have resulted in decreased domestic oil production for 13 years. That trend was broken in 1995 by an oil production capacity increase of 0.4 million barrels per day. In 1998, net petroleum imports were 9.8 million barrels per day, or 51 percent of domestic consumption. In its *AEO2000* projections for 2020, EIA expects crude oil imports to range from 11.42 to 11.71 million barrels per day depending on oil price. The *AEO2000* reference case for 2020 calls for net imports of 11.59 million barrels per day, which is over 65 percent of the total crude supply. Also, natural gas imports are expected to grow from 14.6 percent of total gas consumption in 1998 to 16.3 percent in 2020. These imports are primarily from Canada, which does not represent a supply stability problem, but does represent a drain on balance of payments.

United States coal consumption is equivalent to approximately 3.6 billion barrels of oil per day, which would equate to $44 billion per year. The CCT Program will provide the technologies that will enable coal to continue as a major component in the nation's economy while achieving the environmental quality that society demands. The domestic and export value of 1998 coal production approaches $60 billion in the U.S. economy. Coal related jobs are dispersed through the mining, transportation, manufacturing, utility, and supporting industries.

A U.S. coal conversion industry could directly reduce the nation's dependency on imported oil. The economic impact of adding to domestic oil production or reducing the cost of imported oil is very significant. The CCT Program is responding to this opportunity through development and demonstration of mild gasification and liquid-phase methanol production technologies.

According to EIA's *AER98*, the U.S. exported 84 million tons of coal in 1997. Coal exports to foreign destinations contributed $3.41 billion to the U.S. balance of trade in 1997. Worldwide demand for energy is expected to reach 612 quadrillion Btu by 2020, over 1.6 times the current level. According to the EIA, worldwide coal use in 1996 accounted for about 25 percent of total energy consumption and 38 percent of the energy consumed worldwide for electricity generation. Those market shares are not projected to change substantially through 2020. Exports of U.S. coal are projected to increase to over 58 million tons by 2020.

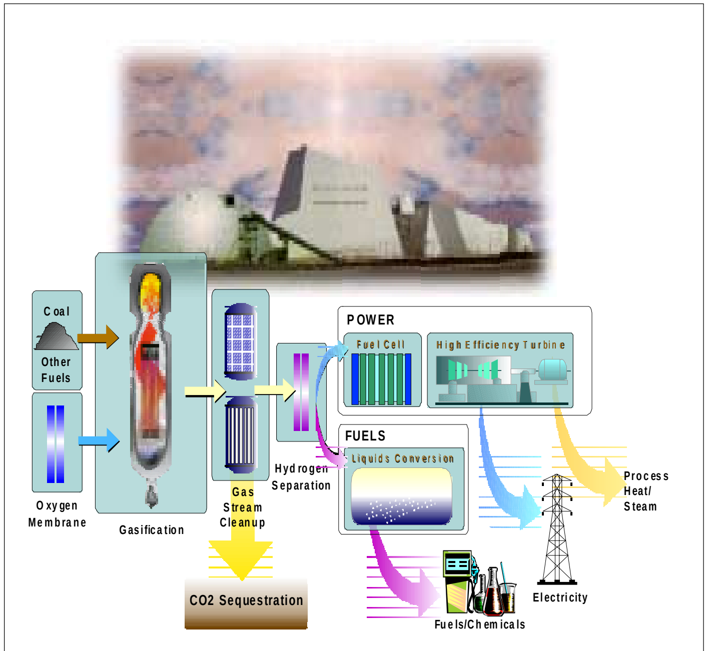
According to the latest DOE projections, the worldwide market for power generation technologies could be as high as $80 billion between 1995 and 2020. Most of the investment will be in developing countries. This market provides opportunities for U.S. technology suppliers, developers, architect/engineers, and other U.S. firms to capitalize on the advantages gained through experiences in the CCT Program. However, aggressive action is needed, as other governments are recognizing the enormous economic benefits that their economies can enjoy if their manufacturers capture a greater share of this market.

Beyond the CCT Program, DOE activities are aimed at creating a favorable export climate for U.S. coal and coal technology. These efforts include: (1) improving the visibility of U.S. firms and their products by establishing an information clearinghouse and closer liaison with U.S. representatives in other countries, (2) strengthening interagency coordination of federal programs pertinent to these exports, and (3) improving current programs and policies for facilitating the financing of coal-related projects abroad.

Coal Technology for the Future

The CCT Program is providing the foundation needed to build a future generation of fossil energy-based power systems capable of meeting the energy and environmental demands of the 21st century. The hardware and attendant databases serve as platforms for power, environmental, and fuels systems that together can meet the long-term goals of the Office of Fossil Energy's Coal & Power Systems Program. These "Vision 21" goals are delineated in Exhibit 1-4. The expected result is a suite of technology modules capable of using a broad range of fuels (coal; biomass; and forestry, agricultural, municipal, and refinery wastes) to produce a varied slate of high-value commodities (electricity, steam, clean fuels, and chemicals) at greater than 60 percent efficiency and near-zero emissions.

First generation systems emerging from the CCT Program provide: (1) the knowledge base to launch commercial systems, which will experience increasingly improved cost and performance over time through design refinement; and (2) platforms to test new components, which will result in quantum jumps in cost and performance. Examples of new components include advanced hot gas particulate filtration, hot gas sulfur and alkali removal, air separation membranes, high temperature heat exchangers, artificially intelligent controls and sensors, and CO_2 and hydrogen separation technologies. A strategy of the Vision 21 effort is to develop and spin off such key components to mitigate the risk and cost of integrating the technologies into power, environmental, and fuel system modules.



▲ Vision 21 modules can be combined in a variety of configurations. Shown is one example of modules to produce a variety of energy products.

Exhibit 1-4
Vision 21 Objectives

Efficiency—Electricity Generation	Coal-based systems 60% (HHV); natural gas-based systems 75% (LHV) with no credit for cogenerated steam.[a]
Efficiency—Combined Heat & Power	Overall thermal efficiency above 85% (HHV); also meets efficiency goals for electricity.[a]
Efficiency—Fuels Plant Only	Fuel utilization efficiency of 75% (LHV) when producing coal derived fuels.[a]
Environmental	Near-zero emissions of sulfur, nitrogen oxides, particulate matter, trace elements, and organic compounds; 40-50% reduction in CO_2 emissions by efficiency improvement; 100% reduction with sequestration.
Costs	Cost of electricity 10% lower than conventional systems; products of Vision 21 plants must be cost-competitive with market clearing prices.
Timing	Major spinoffs such as improved gasifiers, advanced combustors, high-temperature filters and heat exchangers, and gas separation membranes begin by 2004; designs for most Vision 21 subsystems and modules available by 2012; Vision 21 commercial plant designs available by 2015.

[a]The efficiency goal for a plant co-feeding coal and natural gas will be calculated on a pro-rata basis. Likewise, the efficiency goal for a plant producing both electricity and fuels will be calculated on a pro-rata basis.